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Changes in productivity and soil fertility under rice (*Oryza sativa*)–wheat (*Triticum aestivum*) system as influenced by long-term integrated nutrient supply

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ABSTRACT

An experiment carried out for last 11–13 consecutive years at 3 locations, viz. Ludhiana, Jabalpur and Kalyani, of AICRP on Cropping Systems in rice(*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crop sequence revealed that at Ludhiana, application of 50% recommended NPK + 50% N through FYM increased rice yield over years, while wheat yield increased linearly with farmer's practice. At Jabalpur, rice yield showed an increasing trend after 3 years of experimentation in integrated nutrient supply, whereas wheat yield registered upward trend after 5 years with chemical fertilizers and also with integrated nutrient supply. At Kalyani, static trend in rice yield was noticed in chemical fertilizers and some integrated nutrient supply treatments, while linear increase in wheat yield was observed with farmer's practice. Integrated nutrient supply had favourable effect on available NPK at all the locations except N and P at Jabalpur under continuous rice–wheat sytsem. Economic analysis indicated that the maximum net returns of Rs 38,388 could be realized at Ludhiana when 75% recommended NPK + 25% N through green-manuring was applied to rice followed by 75% nitrogen to wheat, whereas the maximum net returns of Rs 27,061/ha/year at Jabalpur and of Rs 22,658/ha/year at Kalyani could be recorded with the use of 50% recommended NPK+ 50% N through green-manuring to rice and 100% NPK to wheat.

Key words : Rice–wheat system, Productivity, Soil fertility, Integrated nutrient supply

Rice–wheat system is a very important cropping system, covering an area of about 10.5 million ha in India and contributes about 75% food to national food basket. With the availability of high-yielding, photo-insensitive and input responsive varieties of rice and wheat and extension of irrigation facilities, cultivation of rice–wheat sequence could be extended to a variety of soil and climatic conditions. However, under a wide range of input use and management, yield trends of rice–wheat

sequence are different in different parts of the country. The yield trends can be known if these are monitored over a number of years in well-planned experiments. Thus in long-term fertilizer experiments, crop yields are the resultant of cumulative effect of treatments applied on the same plot for a number of years. Few reports on crop yield data related to long- term effect of fertilizer application are available, as reported by Soni *et al.* (1988), Narain *et al.* (1990), Katyal *et al.* (1998) and Hegde and Katyal (1998). The present attempt was made to study yield trends over a long period of time, under integrated nutrient management, so as to draw some meaningful conclusions.

MATERIALS AND METHODS

A long-term field experiment is being conducted at Ludhiana since 1983–84 and at Jabalpur and Kalyani centres of AICRP on cropping system since 1985–86. The experimental data up to 1996–97 were utilized for the present study. The characteristics of experimental sites are given in Table 1. In all 12 treatments were tested in randomized block design with 4 replications. The treatments were : T_1, no fertilizer, no organic matter (K, *kharif* or rainy season) and no fertilizer, no organic matter (R, *rabi* or winter season); T_2, 100% NPK dose through fertilizer (K) and 50% NPK dose through feritlizer (R) : T_3, 50% NPK dose through fertilizer (K) and 100% NPK dose through fertilizer (R); T_4, 75% NPK dose through fertilizer (K) and 75% NPK dose through fertilizer (R); T_5, 100% NPK dose through fertilizer N, P and K @ 120, 0, and 0 at Ludhiana; 100, 60 and 40 kg at Jalabpur and 80, 60 and 40 kg at Kalyani during the rainy season while 120, 60 and 40 kg at Ludhiana; 60, 30 and 30 kg at Jalabpur and 100, 60 and 40 kg/ha at Kalyani during the winter season; T_6, 50% NPK dose through fertilizers+50% N through compost or farmyard manure or *gobar* gas slurry (K) and 100% NPK dose through fertilizers (R); T_7, 75% NPK dose through fertilizers+25% N through compost or farmyard manure or *gobar* gas slurry (K) and 75% NPK dose through fertilizers (R); T_8, 50% NPK dose through fertilizers + 50% through crop residues or rural farm waste etc. (rice or wheat cut straw) (K) and 100% NPK dose through ferilizers (R); T_9, 75% NPK dose through fertilizers + 25% through crop residues or rural farm waste etc. (rice or wheat straw) (K) and 75% NPK dose through fertilizers (R); T_{10}, 50% NPK through fertilizer + 50% N through green organic matter (green-manuring) or through *Azolla* (K) and 100% NPK dose through fertilizer (R); T_{11}, 75% NPK dose through fertilizer + 25% N through green organic matter (green-manuring) or through *Azolla* (K) and 75% NPK dose through fertilizer (R); T_{12}, farmer's (conventional) practice, which comprised N, P and K 180, 30 and 0 kg at Ludhiana; 40, 20 and 20 kg at Jabalpur; 100, 30 and 20 kg at Kalyani during rainy season, while 120, 60 and 30 kg at Ludhiana; 25, 12.5 and 0 kg at Jabalpur; and 100, 60 and 40 kg/ha at Kalyani during winter season.

The organic manures like FYM and crop residues were applied before the last ploughing, while green-manuring or green leaf-manuring was done 20 days before planting of rice crop. Full doses of P and K

Table 1. Characteristics of experimental site

Location/character	Ludhiana	Jabalpur	Kalyani
Location	30°56'N	23°10'N	23°N
Longitude	75°52'E	79°57'E	89°E
Average annual rainfall (mm)	681	875	1655
Soil taxtomic class	Ustochrepts	Chromusterts	Fluventic Eutrochrepts
Soil texture	Loamy sand	Deep black	Alluvial
Organic carbon (%)	0.31	0.71	0.92
Available N (kg/ha)	143	273	0.005*
Available P (kg/ha)	11.2	21.0	16.0
Available K (kg/ha)	101	268	80

*Available N (%)

along with 50% of the recommended N were applied basal to both rice and wheat. Remaining nitrogen was top-dressed in 2 equal splits, at 25 and 50 days after planting of rice and wheat. Three years moving average yields were computed from the raw data for selected centres to reduce irregular and cyclical variation of yields (Table 2) and then trend equations in treatment T_5 to T_{12} were fitted and significant values are shown in Table 3.

RESULTS AND DISCUSSION

System productivity

At Ludhiana, yields of rice remained static over years in the treatments involving recommended NPK, 50% recommended NPK + 50% N through FYM, 75% recommended NPK + 25% N through FYM, 75% recommended NPK + 25% N through crop straw, 50% recommended NPK+50% N through green-manuring, 75% recommended NPK+50% N through crop straw, the yields increased linearly (Tables 2, 3). However, wheat yields started declining after 7 years of experimentation in respect of 50% NPK + 50% N through FYM applied in the rainy season, followed by 100% NPK in winter; 75% NPK + 25% N through FYM applied in rainy season, followed by 75% NPK in winter; 50% NPK+50% N through crop cut straw applied in rainy season, followed by 100% NPK in winter; 75% NPK+25% N through crop cut straw applied in rainy season, followed by 75% NPK in winter, while the yield remained static in case of 50% NPK+50% N through green-manuring applied in rainy season, followed by 100% NPK in winter; and 75% NPK+25% N through green manuring applied in rainy season, followed by 75% NPK in winter. But in farmer's practice, yields increased linearly. At Jabalpur, rice yields started increasing after 3 years of experimentation in respect of 50% NPK+50% N through FYM or crop cut straw or green-manuring applied in the rainy season and 75% NPK+25% N through crop cut straw applied in the rainy season (Tables 2, 3). But in farmers practice, yield increased linearly. In other tretaments such as 100% NPK in the rainy season, 75% NPK+25% N through crop cut straw or green-

manuring applied in the rainy season, the yield remained static. On the other hand, wheat yields started increasing after 5 years of experimentation under 100% recommended NPK in both the seasons, 75% recommended NPK + 25% N through crop cut straw applied in the rainy season, followed by 75% NPK in the winter and 50% recommended NPK+50% N through crop straw applied in the rainy season, followed by 100% NPK in winter. Yields remained static under 50% NPK+50% N through FYM or green-manuring applied in the rainy season, followed by 100% NPK in winter and 75% NPK+25% N through crop cut straw or green-manuring applied in the rainy season, followed by 75% NPK in the winter. At Kalyani, rice yields over years remained static in respect of the treatments stated above but wheat yields started increasing after 2 years of experimentation in 75% NPK+25% N through crop cut straw or green-manuring applied in the rainy season, followed by 75% NPK in winter. But yield increased linearly in case of farmer's practice. In other treatments yields remained static (Tables 2, 3).

These results indicated that it was possible to economize fertilizer use to the extent of 25–50% of recommended level when 25–50% N was substituted by FYM or green-manuring (Hegde, 1992). At Ludhiana and Jabalpur, only FYM and green-manuring could substitute a part of fertilizer N, while at Kalyani all the organic sources were able to substitute a part of fertilizer N. The high organic carbon status at Kalyani might have helped in release of required quantities of N when a part of fertilizer N was substituted by organic sources.

Soil fertility

In general, improvement in available soil NPK was observed over their initial levels in continuous rice–wheat cropping system, followed for 13 years and fertilized with inorganic fertilizers in conjunction with organic manures such as FYM, green-manuring and crop residues. The effect of FYM and green-manures was slightly more pronounced than that of crop residues on the build-up of NPK (Table 4). Available soil N increased due to integrated nutrient supply treatments at all locations except Jabalpur where it decreased. This decline in available soil N under these treatments may be attributed to lack of association between organic carbon and available N, as the soil submergence during the rainy season results in structural changes in organic carbon pool which become enriched with phenolic compound that may immobilize N containing compounds (Olk *et al.*, 1996) and results in decline in available N. A considerable build up of available soil P was noticed at Ludhiana and Kalyani. However, decline in available soil P was recorded at Jabalpur which was possibly due to high P-fixing capacity of the soil and due to higher uptake of P than its application to rice–wheat system. Available soil K was found to increase over its initial level. This may be due to release of non-exchangeable K on account of addition of organic manures for utilization of rice and wheat crops.

Economic analysis

It was observed that the maximum net return of Rs 38,388/ha with benefit: cost ratio of 15.50 at Ludhiana can be realized when 75% recommended NPK + 25% N

Table 2. Grain yields (kg/ha) of rice (rainy season) and wheat (winter season) over years in rice–wheat crop sequence at selected centres

Year	Season	Treatment						
		T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
				Ludhiana				
1983	*Kharif* (rainy season)	4,570	4,102	4,186	3,956	4,293	4,585	4,341
	Rabi (winter season)	3,646	3,918	3,167	3,231	2,956	3,858	3,216
1984	*Kharif*	7,292	6,408	6,990	5,681	6,900	7,261	7,843
	Rabi	5,072	5,014	4,494	4,577	4,214	4,883	4,393
1985	*Kharif*	6,840	5,898	6,536	5,421	5,559	,6896	7,022
	Rabi	4,278	4,184	3,611	3,758	3,106	3,997	3,697
1986	*Kharif*	6,426	5,890	5.611	4,534	5,786	6,317	6,511
	Rabi	4,561	4,900	4,456	4,522	4,147	4,492	4,286
1987	*Kharif*	5,835	5,109	5,219	4,712	5,262	5,639	5,687
	Rabi	4,686	4,867	4,667	4,431	4,217	4,607	4,383
1988	*Kharif*	6,792	5,842	6,267	5,879	6,092	6,567	6,850
	Rabi	5,151	5,356	4,744	5,171	6,558	7,061	7,333
1989	*Kharif*	6,421	6,066	6,629	5,479	65,58	7,061	7,333
	Rabi	4,600	5,044	4,397	4,503,	4,194	4,464	4,211
1990	*Kharif*	6,533	6,117	6,447	5,833	6,017	6,673	6,873
	Rabi	4,450	5,500	4,183	4,364	3,900	4,303	4,017
1991	*Kharif*	6,582	6,152	6,396	5,712	6,226	6,476	6,644
	Rabi	4,475	4,797	4,464	4,364	4,106	4,036	3,881
1992	*Kharif*	6,261	5,764	6,039	5,183	5,569	6,267	6,572
	Rabi	4,233	4,433	4,025	4,242	3,531	4,058	3,741
1993	*Kharif*	5,569	5,272	5,492	4,833	5,239	5,333	5,806
	Rabi	4,142	4,686	3,832	4,616	3,676	4,134	3,530
1994	*Kharif*	5,356	5,128	4,442	4,242	3,713	4,033	3,842
	Rabi	4,117	4,938	4,442,	4,242	3,713	4,033	3,842
1995	*Kharif*	5,051	4,424	5,126	4,474	4,963	5,131	57
	Rabi	4,198	4,349	3,871	3,694	3,439	4,124	3,973
1996	*Kharif*	6,092	5,542	5,396	4,437	5,306	5,700	5,818
	Rabi	4,433	4,583	4,239	4,256	3,550	4,222	4,056
				Jabalpur				
1985	*Kharif*	4,005	4,911	4,766	3,396	3,172	4,933	4,286
	Rabi	2,281	2,518	2,388	2,544	1,909	,2263	2,498
1986	*Kharif*	3,938	3,854	3,896	3,531	3,578	3,516	4,260
	Rabi	3,880	3,151	3,182	3,578	2,807	2,625	3,333
1987	*Kharif*	5,313	4,130	5,255	3,656	4,411	5,865	5,779
	Rabi	3,276	2,536	2,774	3,104	1,911	2,146	2,298
1988	*Kharif*	4,865	3,305	4349	3667	3865	4589	4865
	Rabi	Failed						
1989	*Kharif*	3,412	3,301	3,854	3,072	2,656	3,482	3,512
	Rabi	1,668	1,614	1,678	1,429	1,459	1,445	1,352

Table 2. *Continued*

Year	Season	Treatment						
		T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
1990	*Kharif*	4,902	4,720	5,246	4,443	4,744	5,264	5,189
	Rabi	2,549	2,684	2,123	2,416	2,486	2,785	2,139
1991	*Kharif*	6,340	6,156	6,348	5,475	5,748	6,633	6,473
	Rabi	2,883	2,879	2,555	2,699	2,377	2,936	2,707
1992	*Kharif*	4,979	4,339	4,526	3,839	4,039	4,711	4,974
	Rabi	2,208	2,371	1,772	2,490	1,631	2,590	1,870
1993	*Kharif*	4,789	5,168	4,844	4,922	5,014	5,750	5,326
	Rabi	2,410	2,636	2,102	2,553	1,893	2,355	2,244
1994	*Kharif*	5,203	5,083	5,156	5,328	5,199	5,996	4,915
	Rabi	3,261	3,465	3,137	3,543	2,502	3,890	2,961
1995	*Kharif*	8,473	7,726	7,937	7,162	7,723	7,043	7,1113
	Rabi	2,136	1,810	2,000	1,605	1,792	2,312	1,998
1996	*Kharif*	4,836	4,690	4,680	4,022	4,125	4,832	4,704
	Rabi	3,047	3,171	2,908	3,106	2,841	3,200	2,968
				Kalyani				
1986	*Kharif*	3,262	3,125	3,475	3,200	3,200	3,512	3,625
	Rabi	2,070	2,540	2,250	2,8,00	2,080	22,940	2,530
1987	*Kharif*	3,366	3,093	3,760	3,184	3,278	3,926	3,885
	Rabi	3,724	3,929	3,357	3,735	3,107	3,617	2,368
1988	*Kharif*	4,490	4,643	4,378	4,311	4,327	4,378	4,500
	Rabi	2,459	2,878	2,490	2,944	2,112	3,912	3,909
1989	*Kharif*	3,413	2,740	3,709	3,184	3,270	3,929	3,909
	Rabi	2,250	2,449	2,383	2,694	1,954	2,077	1,857
1990	*Kharif*	3,357	3,347	3,612	3,153	3,469	3,327	3,602
	Rabi	2,689	2,837	2,847	3,133	2,903	3,087	2,765
1991	*Kharif*	2,806	2,816	3,041	3,010	2,903	2,786	3,026
	Rabi	2,944	3,184	2,587	3,270	2,755	3,209	2,327
1992	*Kharif*	3,726	3,995	4,327	4,286	3,724	4,311	3,893
	Rabi	2,429	2,668	2,724	2,872	2,934	2,872	2,628
1993	*Kharif*	2,699	2,847	3,015	2,801	2,852	2,939	2,934
	Rabi	2,594	2,959	2,821	2,980	3,005	3,148	2,944
1994	*Kharif*	2,949	3,179	3,245	3163	3,077	3,148	3,061
	Rabi	2,551	3,041	2,872	3,153	2,801	3,163	2,796
1995	*Kharif*	3,010	3,087	3,474	3,010	2,939	3,316	2,985
	Rabi	2,617	2,745	2,735	3,214	2,546	3,296	3,041
1996	*Kharif*	3,112	2,934	3,138	3,342	3,265	3,393	3,296
	Rabi	3,138	2,898	2,832	3,240	2,679	3,265	3,087

Details of treatments are given in text

through green-manuring were applied in the rainy season followed by 75% NPK in winter. While the maximum net returns of Rs 22,658 with benefit : cost ratio of 6.80 at Kalyani and Rs 27,061/ha with benefit : cost ratio of 7.45 at Jabalpur could be obtai-

Table 3. Trends equations at different locations under integrated nutrient management

Location Treatment	Equation	R^2
	Ludhiana	
T_8 (K)	Y= 4,655+123.94 t	0.66*
T_6 (R)	Y = 3,716+370.6.2t-23.26 t^2	0.90*
T_7 (R)	Y = 2,717+630.51 t-53.63 t^2	0.93**
T_8 (R)	Y= 2,810+618.42t-51.42 t^2	0.88**
T_9 (R)	Y = 2,379 +612.32 t-49.79 t^2	0.90**
T_{12} (R)	Y = 1,115+33.20 t	0.85**
	Jabalpur	
T_8 (K)	Y = 3,107 +219.74t	0.78*
T_{12} (K)	Y = 2,152+158.9t	0.66*
T_7 (R)	Y = 2,903 +124.1t	0.77*
	Kalyani	
T_9 (R)	Y = 2,712-336.32t +72.9 t^2	0.97**
T_{11} (R)	Y= 2,418-337.5t+74.9 t^2	0.95**
T_{12} (R)	Y = 1,505+111.3t	0.65*

Details of treatments are given in text
K, Rainy season; R, winter season

Table 4. Soil fertility status under integrated nutrient supply after 13 years of continuous rice–wheat system

Treatment	Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
	Ludhiana	Jabalpur	Kalyani	Ludhiana	Jabalpur	Kalyani	Ludhiana	Jabalpur	Kalyani
T_5	171	263	0.058*	17.6	15.8	21	106	732	225
T_6	166	268	0.068	50.3	16.0	27	118	774	195
T_7	155	266	0.068	30.0	13.8	36	112	796	195
T_8	166	273	0.063	18.8	17.6	27	112	790	150
T_9	153	263	0.059	16.6	15.6	27	120	802	185
T_{10}	167	263	0.063	21.9	16.8	18	115	782	140
T_{11}	165	260	0.071	17.1	17.4	24	112	812	140
T_{12}	171	252	0.064	36.5	17.0	36	119	760	150

Details of treatments are given in text
*Per cent total N

Table 5. Economic analysis of rice–wheat system under integrated nutrient management

Treatment	Net returns (Rs/ha)			Benefit : cost ratio		
	Ludhiana	Jabalpur	Kalyani	Ludhiana	Jabalpur	Kalyani
T_1	13,128	13,671	8,699			
T_2	27,199	18,715	14,015	18.23	8.79	7.06
T_3	32,972	21,984	16,202	12.93	6.81	5.38
T_4	33,574	24,417	18,563	15.00	7.64	6.23
T_5	28,968	25,720	19,731	10.21	6.04	4.97
T_6	35,957	23,355	19,911	7.26	4.47	4.32
T_7	36,304	24,763	21,118	10.56	5.90	5.59
T_8	4,499	– 1,181	2,513	0.14	– 0.04	0.11
T_9	21,591	10,293	10,541	1.25	0.66	0.81
T_{10}	38,201	27,061	22,658	12.61	7.45	6.80
T_{11}	38,388	25,945	20,565	15.50	7.64	6.55
T_{12}	20,435	18,309	15,630	5.22	15.54	4.54

Details of treatments are given in text

ned when 50% recommended NPK + 50% N through green-manuring were applied in the rainy season, followed by 100% recommended NPK in winter (Table 5).

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